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Straintronics in 2D semiconductors

Two-dimensional transition metal dichalcogenides (TMDs) have been investigated for applications in optomechanics and optoelectronics thanks to their properties (thickness, high Young modulus, very low mass and direct bandgap in monolayers). The control over strain is at the heart of many new applications in these fields. To highlight the interest of this topic, we achieve strong strain tuning in suspended 2D materials via thermal expansion and tip indentation.
First, we propose a new scheme to tune efficiently the mechanical vibration of 2D suspended membrane. We investigated the efficiency of electrothermal tuning of the vibration of MoS_2 nanoresonator using Joule heating and thermal dilatation to slightly change the intrinsic strain and modify the resonant frequency using the nano-opto-elctro-mechanical platform (NOEM) shown in Figure 1. Considering these properties, we extract the thermal conductivity and demonstrate a good temperature sensitive device with a resolution of about 20mK.
Second, to reach higher strain regime, we apply a local force on the membrane with an AFM tip indentation which strongly tune the optical bandgap. The non-uniform strain, obtained in this system, leads to the diffusion of the excitons[2] and the conversion of excitons to trions[3]. We investigated locally the properties of a suspended membrane of $WS_{1.3}Se_{0.7}$ under non-uniform strain exploiting the tip enhanced photoluminescence (TEPL) under the AFM tip shown in Figure 2.

References

[1] Jaesung Lee et al., ACS Nano 2013 7 (7), 6086-6091
[2] Hyowon Moon et al., Nano Letters 2020 20 (9), 6791-6797
[3] Harats, M.G., Kirchhof, J.N., Qiao, M. et al. Nat. Photonics 14, 324–329 (2020).

Figures

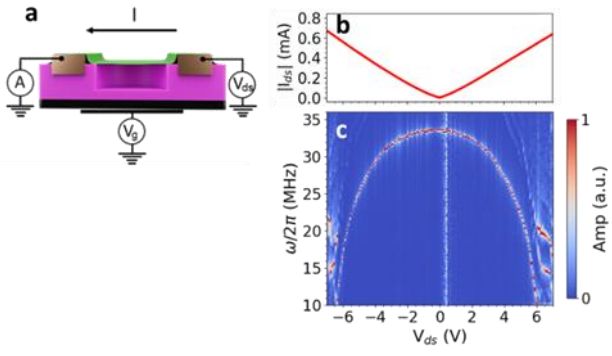

Figure 1 : a) Electrothermal setup. b) Current tension characteristics of the device. c) Very efficient electrothermal frequency tuning of the nanodrum due to the strain variations.

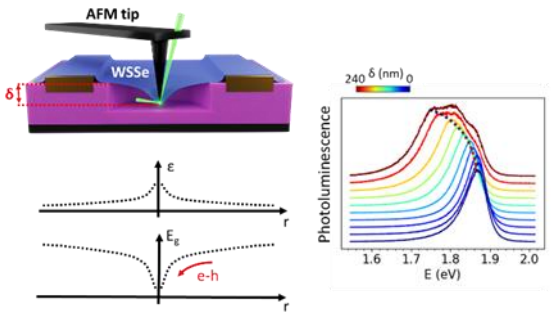

Figure 2 : a) Tip indentation setup. b) The tip indentation induces non uniform strain on the 2D semiconductor changing the gap locally. c) Variation of photoluminescence with respect to height variations of the center of the membrane.